EFFECTS OF SUCROSE CONCENTRATION AND DIETARY CARBOHYDRATE LEVELS UPON INGESTION OF SUCROSE SOLUTIONS BY RATS

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CHAPTER I

HEDONISM AS AN EXPLANATION OF MOTIVATION

One of the many explanations put forth to explain motivation is the principle of hedonic processes. Hedonic processes refer to events concerned specifically with the continuance of a positive emotional state and with the avoidance of a negative emotional state within the organism. The affective states often act as motivators for behavior. As such, these states may initiate, maintain, or terminate the organism's behavior, or even bring into functioning other motivators (Young, 1955). The presence of an affective state aroused by a given stimulus may lead to the organism's being motivated to possibly approach or avoid the stimulus. The type of behavior that is elicited by the stimulus will depend upon the affective state aroused and whether or not the organism seeks continuance of that state. Thus, the affective state would lead to the organism's being motivated to respond in a certain manner to the stimulation. The outcome of the competition among factors present in the situation will be in accordance with Young's (1950) basic principle of hedonism--*i.e.*, maximizing positive affect and minimizing negative affect. By means of hedonic processes regulating behavior, the basis is formed for the characteristic direction of later acquired motives (Young, 1955).

The role played by affective processes in hedonic organization is a major one. Young (1959) viewed this role as being composed of three subsections. The first section is seen as one of activating neuro-behavioral patterns. The second is one of regulating and directing behavior. Finally, the third is one of organizing neurobehavioral patterns. For example in a given situation, an organism receives stimulation and later returns to the situation to obtain more of this stimulation, then a positive affective process can be assumed to have been aroused. The source of stimulation may be some type of preferred food stuff or it may be electrical stimulation or whatever. The point is that through the organism's returning for more of the stimulation, a positive affective state is assumed. On the contrary, though, should the organism receive stimulation and then avoid not only the place where stimulation was received, but also any additional stimulation; then, a negative affective state may be assumed to have been aroused. Again, the type of stimulation is not important; but, rather, the effect of the stimulation on the organism is of major concern. The affective process aroused is in both cases assumed to be the cause or source of the behavior exhibited. Young (1955) has stated that the strength and permanence of the behavior pattern is a function of the intensity, frequency, and length of affective arousal. Affective processes may organize behavior in a means other than just strict stimulus approach or avoidance. Rather, continued exposure to a positive stimulus will lead to satiation and with the occurrence of satiation, the positive affect decreases and the negative affect increases.

Using food acceptance studies, Young (1952) found that affective processes operate in a dual manner. Initial contact with the food leads to an immediate affective arousal as a function of some palat-ability effect. Subsequently, after a delay, there is organic relief from stress. This stress is a result of deficiency states--*i.e.*, needs, within the organism. Fulfillment of the need leads to the gradual reduction and final disappearance of the associated stress. The palatability level of the food is to some extent a function of the deficiency condition of the organism; in that, generally the palatability level is increased if the food is needed to fulfill a deficit within the organism (Young, 1952). Basically, the affective processes are dependent upon the interaction between the bodily state of the organism and the actual physical characteristics of the food. In addition to organic deficit conditions, factors such as eating patterns, injuries, diseases, and constitutional conditions will assist in determining the organism's organic state at any give time (Young, 1952). The palatability of a food is generally referred to as its hedonic value; this hedonic value is a result of the interaction of sensory properties, *e.g.*, taste and smell, and environmental properties, *e.g.*, setting, place, and circumstances surrounding eating (Young, 1959).

Through food preference experiments, Young (1952) found that the relationship between test food and acceptance is not constant, but is dependent upon conditions surrounding the test. Involved in the test conditions are such factors as prior exposure to a certain food, deprivation states within the organism, lack of initial preference for test foods, or habit preferences of the organism. A food preference may be reversed by allowing the animal access to a preferred food prior to the preference test. In such a situation, with approaching satiation the level of acceptability falls, although the type of food remains unchanged. If an animal is deprived of a food that is non-preferred, although required for adequate nutrition, such deprivation will force a change in preference, so that the formerly non-preferred food is now preferred. In this situation, the level of acceptability rises, and the original preference changes in agreement with bodily needs. Young (1952) found that a preference would eventually develop for one of two test foods, although initially there was no preference. In such a situation, while the test foods differ in kind, the acceptability level remains the same for a considerable period of time. In determining food selection, Young (1959) found that the established habit preferences of the animal predominated over other factors. Established preference in foods was maintained by the animal even when the established preference differed from bodily need requirements or palatability preferences. However, the fact of established preference predominating over bodily need preferences weakens as the bodily need becomes greater; with time the preference of habit over palatability also weakens. For example, in a situation in which an animal has been satiated on a preferred food, following termination of satiation feeding original preference for that food does not immediately return. However, the original preference will gradually return (Young, 1959). Once established, habit tends to predominate in food intake regulation, until factors of bodily need or time lapse become great enough to override habit. Prior to any statement regarding the relationship between the organism and his preference for a test food, factors concerned with the state of the organism; his prior experiences, and his organic requirements must be considered for their possible effects on preference and intake regulation.

Food incentives may still arouse an organism to act, even when the organism has no dietary deficiency and the incentives are not needed

(Young, 1955). All parents are familiar with effect of using candy as a reward for a child's behavior. Effective as that candy may be as a reward, it is not required for growth, homeostasis, or to meet any need; yet, it is still effective as a reward. Similarly, laboratory rats will work for the sweet taste of a saccharine solution, although that solution meets no known metabolic need (Sheffield and Roby, 1950). Acceptance of a sweet-tasting substance is dependent neither on a bodily need nor on a state of hunger (Smith, Pool, and Weinberg, 1962). Rather, the sweet taste is in itself pleasurable and, as such, contributes to establishing a positive affective state, which acts as a motivator.

In situations in which more than one preferred solution was used, rats have found to prefer the sweeter of two fluids and to consume it more continuously and consistently than a less sweet fluid (Young, 1955). In an experiment by Shuford (1959) on paired isohedonic solutions of glucose and sucrose, the initial rate of acceptance of the two fluids in each pair was found to be practically the same. However, more detailed examinations of the data showed that the highest acceptance rate was for the pair of highest concentrations and the lowest rate for the pair of lowest concentrations. These results lend support to the belief that the sweeter the solution, the greater the amount ingested.

With an understanding of how hedonic processes are assumed to motivate behavior, one can now look at some of the aspects by which these processes actually mediate behavior. Dealing specifically with food acceptance, various factors have been postulated to account for the amount and type of a given food that is ingested. These factors include palatability, obesity, taste and smell, concentration, bulk, and calories. In the next chapter, these factors are studied and reviewed so as to determine which factor(s) seems to predominate in the determination of amount and kind of food ingested.

CHAPTER II

REVIEW OF LITERATURE

Palatability

The palatability level of a food has been used to account for not only the type of food ingested, but also how much of a given food is ingested. The relationship between this factor of palatability and food intake and obesity was studied by Corbitt and Stellar (1964) using both normal and hyperphagic animals. From their results, support is given to view that palatability regulates not only the amount of food ingested, but also body weight that is maintained by the animal. Although their concern was primarily with the effect of palatability upon the intake regulation of hyperphagic rats, the results obtained on the effect of palatability upon intake regulation in normal rats were similar. Like the hyperphagic rats, the normal rats showed an increase in food intake and amount of body weight gained when placed on a high-fat diet. However, the increases manifested by the hyperphagic rats were greater than those of the normal rats. An initial explanation of these results would be that the increases were due to a failure on the part of the rat to make a proper adjustment of their caloric intake when placed on the high-fat diet. Such an explanation was examined by means of a comparison test using diets of different caloric density, yet of equivalent palatability. A mineral-oil diet was paired with the high-fat diet; the mineral-oil diet was equal in caloric density to the lab chow diet, but its stimulus properties were equivalent to those of the high-fat diet. The results indicated that both groups reached levels of food intake and body weight that were equal to the levels reached by the high-fat diet groups in the initial test. With these results, the high intake level of the high-fat diet appears to be due not to the increased caloric density of the diet; but, rather, to the stimulus properties associated with that diet.

Obesity

The preceding study by Corbitt and Stellar (1964) investigated the effect of obesity on food intake, as well as the effect of palatability on food intake. With hyperphagic rats, they found obesity operating in an inhibitory manner; however, this same inhibitory property of obesity was found to be operating in normal rats also. The results suggest an inverse relationship between body weight and food intake. Similar results have been obtained in other studies in which the relationship between obesity and food intake has been studied. Experiments by Cohn and Joseph (1962) and Hoebel and Teitelbaum (1961) found that through forced feeding, obesity could be obtained; however, when such forced feeding was discontinued, body weight dropped to levels equal to pre-experimental levels. Food intake was found to vary only so as to maintain a certain level of body weight for the animal. This weight level, while showing variation across individual animals, appears to be fairly uniform across the species. Apparently the organism is sensitive to initial unusual weight gains which make the organism aware that obesity is beginning. These early indications of obesity then trigger some mechanism within the organism which in turn brings about careful regulation of food intake. One explanation for this mechanism is that the central nervous system is sensitive to early indications of obesity (Corbitt and Stellar, 1964). Such sensitivity, when aroused, would bring about close regulation of food intake in order to remove the signs of obesity and, thereby, to reduce the sensitivity. Another explanation of a possible mechanism by which obesity regulates body weight is offered by Brobeck (1948), Brooks (1946), and Teitelbaum (1957). In this mechanism, obesity impairs the ability of the organism to regulate body temperature. This impairment is presumed to be due to the interference of fatty tissue with the temperature regulators. The fatty tissue appears to impair the organism's ability to dissipate body heat. Thus, obesity appears to regulate food intake, but only as it is related to the state of obesity. When obesity is present, the food intake of the organism is lowered so as to facilitate the removal of excess body weight by normal bodily processes involved in the metabolism of excess fatty tissue.

Taste and Smell

Taste and smell through their close relationship to the physical stimulus properties of the food stuff have been suggested as the determining factors of food intake regulation. These factors have been suggested as determining initial intake of food, for their role as a determinant lessens over time. Rather, taste and smell appear to determine initial preference in food choice and to regulate the intake of that chosen food upon initial presentation. However, as time progresses, the role of taste and smell decreases as apparently stronger motivators take control. Caloric need appears to be the factor which becomes the primary determinant, when taste and smell are no longer operating. Evidence for this predomination of caloric need over sensory characteristics of the food stuff is given by the fact that animals maintain caloric intake in spite of changes in the diet available. Animals have been shown to maintain caloric balance in their diet by means of overeating when the caloric density of the diet is reduced (Teitelbaum and Epstein, 1962). Through such increased ingestion, the bodily weight of the animal will be maintained, until the caloric density of the food becomes too low--2.0 cal/gm (Smith, Pool, and Weinberg, 1962). When the amount of bulk present in the diet becomes too great, the physical limitations of the stomach of the organism will prevent the ingestion of the adulterated food in great enough quantities to maintain the caloric requirements of the organism. The animal will eat as much as he is able to in order to survive. The ability of the animal to eat more of the adulterated diet may be improved by mixing the diet with water. Such a diet will force the animal to accept overhydration as a consequence of ingesting enough food to survive (Adolph, 1947).

The use of taste and smell alone is not sufficient to account for the regulation of intake by animals. Rather, caloric need appears to be the major factor with taste and smell aiding in the determination of initial preference. Once the regulation of intake has been established according to caloric need, taste and smell factors are unable to change the intake pattern (Teitelbaum and Epstein, 1962). In fact, neither improving or worsening the taste and/or smell of a food would change the intake pattern. Teitelbaum and Epstein (1962) found that the addition of quinine hydrochloride in almost toxic amounts to a food necessary for bodily maintenance would fail to prevent ingestion. Actually, the complete absence of taste and smell in the animal will have little effect on the intake patterns. In spite of complete removal of one or both sense modalities, the animal will neither terminate nor change his food intake or preferences. Rather, taste and smell appear to operate as a factor secondary to the primary factor of caloric need. Until caloric need has been satisfied, taste and smell do not determine or regulate the ingestion of food. Once the caloric need is satisfied, then taste and smell may come into view. As such, they may then aid in the selection of one food from among many which would meet caloric requirements.

Concentration

The role played by concentration in the determining of the amount of a solution ingested is closely related to the satisfaction of the animal's caloric need. Concentration becomes an important factor, only after the means for assuring the gratification of the caloric need have been established. Given a choice between differing concentrations of the same solution, animals will ingest the higher concentration in greater amounts than the lower concentration. In this situation, factors other than just concentration contribute to the results obtained. In a situation in which caloric needs have been satisfied, the factor of palatability leads to the preference of higher over lower solution concentrations; for, generally, the more concentrated solutions are the more palatable. Thus, Young and Greene (1953) found that as sucrose solutions were made more concentrated, the animals drank more of the solutions. However, such a statement must be qualified by denoting the means of presentation of the solutions. As long as the method used is one of brief exposure to solutions, the preference for higher concentrations holds; however, in continuous choice situations, the preferred solution is often not the most concentrated (Young and Greene, 1953). Rather, concentration and palatability interact to determine the solution preference as long as caloric needs are met. With that condition in mind, amount ingested increases as the concentration increases and the animal is allowed only brief exposure to the test solutions (Young and Shuford, 1955).

Bulk

Bulk will determine intake of food, as long as caloric needs of the animal are met, for otherwise, caloric need predominates over all other factors, such as bulk. When animals are able to maintain the caloric balance, they will adjust their intake in response to bulk present so as to maintain their caloric intake at a relatively constant level. Bulk is a problem which the animal can partially overcome through decreasing body weight and thereby lowering caloric requirements. However, this adjustment is only partial as the animal will, through experience with the diet, slowly increase weight depending on the availability of nutrient in the diet. The primary factor concerning bulk is that there must still be enough nutrient present for the maintenance of the caloric balance of the animal. Smith, Pool and Weinberg (1962) found that the most critical point in bulk adjustment is the initial adjustment period. There must be enough nutrient present in the diet at this time or the animal will starve. The diet may be lowered still more in nutrient level later in the study. However, starvation at this initial time is primarily a result of the inability of the stomach of the animal to hold enough of the diet, so that the animal may still meet his pre-experimental caloric requirements. With experience with the adulterated diet, the animal can lower his caloric requirements. Bulk is an intake regulation factor, only so long as enough nutrient is present in order to meet caloric needs. As bulk increases, the amount of food ingested increases as a result of the animal needing more of the adulterated diet in order to get the same relative amount of calories as before adulteration of the diet. As a regulator of intake, bulk is intimately connected with the maintenance of caloric requirements.

Calories

The earlier sections have set forth various factors--bulk, concentration, taste and smell, and palatability--as being the primary motivators for behavior. However, each of the factors was dependent in some way upon the satisfaction of caloric need. These factors act in an accessory manner to the predominating role of calories. As such accessory motivators, these factors do not come into prominence until the bodily needs of the organism have been met. Once the needs of the organism have been satisfied, then the preference for and intake of various foods depends upon the interrelationships of these factors--*e.g.* palatability, taste and smell, bulk, and concentration. If the organism is normal and nondeprived, factors concerned with the stimulus characteristics of the food, most specifically palatability, will determine intake. However, if a deficiency situation exists, then satisfaction of this need will predominate over other factors.

Presumably, hedonic processes, as motivators of behavior, come into importance when caloric requirements have been fulfilled.

CHAPTER III

STATEMENT OF THE PROBLEM

The experiment was concerned with determining the amount of sucrose ingestion in rats as a function of sucrose solution concentration and carbohydrate diet level. The sucrose solutions varied in concentration (1.0 M, .5 M, and .25 M) and were paired in two-bottle presentation with tap water. The animals were placed on either a high carbohydrate or normal carbohydrate diet throughout the experimental period. The goal of the experiment was to demonstrate that palatability factors would predominate and, consequently, that the rats would ingest enough sucrose to become obese. It was anticipated that due to the higher palatability associated with the increasing concentration of sucrose, the higher concentration would cause the greatest weight gain. The type of diet was expected to have a potentiating effect upon weight gain because the higher the nutrient level of the diet the more food ingested. The diet's effect would add to the effect of whatever solution the animal was on. Thus, it was assumed that this experiment would lend support to the influence of palatability in determining sucrose intake, through the experimental use of sucrose solutions of widely varying palatability levels.

CHAPTER IV

METHOD

Subjects

Forty-eight female albino rats of the Sprague-Dawley strain, aged 50 days, were used in the experiment. They were fed Purina laboratory chow pellets *ad libitum* from the time of arrival in the laboratory until the start of the experiment, a total of 5 days. The room temperature was maintained from 20 to 27.8 degrees Centigrade, and the humidity varied between 30 and 69 percent.

Apparatus

The rats were housed in individual cages measuring 8x8x12 inches which were mounted in a standard laboratory cage rack. All solutions were presented in glass drinkers (300 ml and 100 ml). The drinkers were however paired so that drinkers of the same size were presented to each rat. Liquid intakes from the drinkers were measured to the nearest .1 ml. Diets were presented in aluminum food cups (3 inches in diameter) and the cups were weighted so as to prevent the rat from overturning them.

Preliminary Procedure

The rats were randomly assigned to one of the eight experimental groups. There were six rats in each of the groups. The experimental design as shown in Table I consisted of each group being designated by a solution and a diet type. The groups were 1.0 M--high carbohydrate, 1.0 M--normal carbohydrate; .5 M--high carbohydrate, .5 M--normal carbohydrate; .25 M--high carbohydrate, .25 M--normal carbohydrate; and tap water--high carbohydrate, tap water--normal carbohydrate.

TABLE I

EXPERIMENTAL DESIGN

Solution	High Carbohydrate	Normal Carbohydrate
Tap Water	6 Animals	6 Animals
.25 M Sucrose	6	6
.5 M Sucrose	6	6
1.0 M Sucrose	6	6

The ingredients in the normal and high carbohydrate diet are presented in Table II. Within each cage, the positions of the sucrose and tap water bottles were switched every twenty-four hours. The animal's weight at the start of the experiment was recorded, and later weight readings were taken every five days, during the experimental period of forty-five days.

TABLE II

DIET CONTENTS

Ingredients	High Carbohydrate %	Normal Carbohydrate %
Sucrose	68	52
Casein	18	18
Corn Oil	8	8
Wheat Germ Oil	2	2
Salt Mixture	4	4
Alphacel	--	16

CHAPTER V

RESULTS

The data were studied to determine if there was an effect on fluid intake, weight gain, and sucrose intake as a function the type of diet, solution concentration, or a diet by solution concentration interaction.

Fluid Intake

The rats' intakes of fluid were measured every twenty-four hours. Results from an analysis of variance (4x2) are shown in Table III. F tests performed on these data failed to show significant relationships at the .01 level between diet level or diet by solution concentration interaction and the amount of fluid ingested. However, a significant F was obtained (37.543, df = 3/40, $p < .01$) for the data resulting from the effect of concentration level on the amount of fluid ingested. This significant relationship is, however, a negative relationship. From Figure 1, one can see that the lower the concentration of sucrose the greater the fluid intake.

Considering Figures 2-5 *in toto*, one can see a between subject difference in the amount of fluid ingested which appeared to increase as the concentration level increased. In Figure 2, the average amount of fluid ingested ranged from 18.6 to 26.0 ml. When the data obtained on the two separate diets are considered, the amount of fluid ingested ranged from a low of 12.5 ml to a high of 29.9 ml. However,

TABLE III

SUMMARY OF ANALYSIS OF VARIANCE FOR FLUID INTAKE DATA

Source	df	MS	F
Carbohydrate Levels (Diets)	1	6.88492	.019540
Concentration Levels	3	13227.48706	37.542515*
Carbohydrate x Concentration Interaction	3	8.14388	.023114
Error	40	352.33353	
Total	47		

*Significant at .01 level

this wide range does not appear to have been a function of the type of diet, as both low and high fluid intake values were obtained for animals on both diets. Rather, the range appears to be due to individual variation. In Figure 3, the average amount of fluid ingested varied between 40.1 and 62.6 ml. The range, when the data for the two diets are considered, is from a low of 33.4 to a high of 72.6 ml. However, in Figure 3, as in the preceding one, high and low values for fluid intake were obtained from rats on both types of diets. The range here may again be attributed to variation among the individual rats. In Figure 4, the range of the average amount of fluid accepted is from 69.6 to 112.1 ml. However, looking at the data for the individual diets, one finds the range is from 40.8 to 138.3 ml. The amount of fluid ingested was not correlated with either diet, as rats on both diets showed both high and low intake amounts. The range in the amount of fluid ingested may be attributed to individual variation in the rats. In Figure 5, the average amount of tap water ingested by the rats ranged from 22.8 to 31.7 ml. However, looking at the data for the diets, the amount of fluid ingested ranged from 20.8 to 40.6 ml. In Figure 5, one can again attribute the results to individual variation. Since no diet was consistently above or below the other in amount of fluid ingested, one cannot attribute to the diet the function of determining the rat's fluid intake. Rather, the primary factor that can be said to be operating is one of caloric need. A caloric factor is said to be functioning because the lower the concentration of the sucrose solutions, the higher the intake level. The reason for this increasing of intake of the lower concentration would be to enable the rat to ingest the same relative amount of sucrose as that ingested by a rat on a higher sucrose concentration. Palatability, had it been operating, would have caused the higher concentration of sucrose to be ingested in greater amounts.

The fact that a relationship was found between concentration level and the amount of fluid ingested would normally lead one to predict that possibly palatability was determining the amount of intake as would be evidenced by one concentration being preferred to another. However, the direction of the relationship, i.e., the lower concentration causing the greatest fluid ingestion, requires one to question such an interpretation. If palatability were operating as the prime factor, the sweeter solutions, at least the .5 M, would have been expected to produce the greater fluid ingestion. In the .25 M solution, which was the solution closest to the control solution--tap water--the greatest intake of solution was apparent. Even if the palatability was operating in a reverse manner i.e., from least sweet to most sweet, the results would be expected to show a progressive decrease in the amount of fluid ingested. Such results were not found. Rather, caloric requirements can be predicted to be the primary factors in determining fluid ingestion. If these factors are operating, then the results would be expected to show that the lower the concentration, the greater the amount of fluid ingested. Such results would be expected due to the bodily needs of the animals necessitating more of the lower concentration of fluid in order to maintain caloric requirements. The type of diet can be assumed to have played only a minor role in influencing caloric intake. Rather than potentiating the effect of the solutions, it served only to account for slight changes in the amount of fluid ingested.

Weight Gain

The subject's weight gains were recorded every five days. Figures 6-9 show the range in grams of body weight over which the average weight gains of the rats was plotted. The range of the average weight gain appears to be fairly consistent over the four solutions. In Figure 6, the average weight gain ranged from 2.7 to 6.1 gm. In Figure 7, the range of the average weight gain was from 2.4 to 5.0 gm. In Figure 8, the average weight gain range was from 4.0 to 7.2 gm. In Figure 9, the average weight gain for the control group ranged from 2.6 to 4.0 gm. In each of the Figures 6-9, the range was much broader when the data for the two diet types were studied. However, rather than one type of diet predominating, the low and high values occurred for animals on both diet types. Therefore, the amount of weight gained was not found to be dependent upon either concentration level or diet level.

An AOV (4x2) was performed on the data obtained for the amount of weight gained, and the results are shown in Table IV. From the F test, no significant relationship at the .01 level was shown between either diet level, concentration level, or their interaction and the amount of weight gained. The F value for concentration level was not significant at the .01 level; however, at the .05 level, the value is significant (required F of 2.84, df = 3/40).

In an experiment of this nature, care must be exercised in attributing significance to factors in order to make certain that any variation is due to the factor(s) in question and not due to some type of error present in the experiment. Therefore, the .01 level is used throughout the experiment so as to attribute significance to factors only when one is fairly certain that the significance is, in fact, due to the factor(s) in question. While running the risk of failing to attribute significance when in fact it is present, such a risk is preferable to attributing significance when in actuality it is not present. Thus, one is unable to accept the .05 level of significance in this instance and will, therefore, reject the possibility of concentration level determining the amount of weight gained.

These results concerning weight gains also cast doubt on the possible role palatability played in determining solution intake. If one proposes that palatability were the main determinant, the results would be expected to show a difference in amount of weight gained depending upon the sucrose solution available to the rat. This difference

TABLE IV

SUMMARY OF ANALYSIS OF VARIANCE FOR WEIGHT GAIN DATA

Source	df	MS	F
Carbohydrate Levels (Diets)	1	4.27094	1.737941
Concentration Levels	3	9.13761	3.718299
Carbohydrate X Concentration Interaction	3	1.63776	.66441
Error	40	2.45747	
Total	47		

would be expected, even if it is allowed that palatability might operate in a reverse sense as would have been shown by the rats' preference for the low to the high concentration. However, the animal's caloric requirements appear to be the main considerations in fluid intake determination. With the above as requirements, and given the fact that the rats were of the same variety, one would be led to anticipate very similar weight gains. Therefore, the weight gain data would give credence to the belief that caloric factors, rather than palatability, are operating to regulate intake.

Sucrose Intake

The subject's sucrose intakes over every twenty-four hour period were determined from the data collected on the amounts of fluid ingested per rat per day. The following values were used to compute the amount of sucrose ingested: .324 gm/ml for 1 M, .171 gm/ml for .5 M, and .086 gm/ml for .25 M. These conversion figures were used to transform the data concerning sucrose solutions intake into data concerned with actual sucrose ingested removed from the water contained in the solutions. An analysis of variance (4x2) was performed on the amount of sucrose ingested. In Table V, the F test, shows that there was no significant relationship (at .01 level) between either diet, concentration, or diet by concentration interaction and the amount of sucrose ingested.

TABLE V

SUMMARY OF ANALYSIS OF VARIANCE FOR SUCROSE INGESTION DATA

Source	df	MS	F
Carbohydrate Levels (Diets)	1	.01369	.002484
Concentration Levels	2	5.54813	1.007011
Carbohydrate X Concentration Interaction	2	0.14213	.025797
Error	30	5.50950	
Total	35		

In Figures 10-12, the average sucrose intakes of the rats are plotted. Here as in Figures 2-9, the ranges of the averaged values are fairly constant over the three sucrose concentrations. In Figure 10, the range of the average sucrose intake is from 5.6 to 8.8 gm. In Figure 11, the average sucrose intake ranged from 6.8 to 10.7 gm. In Figure 12, average sucrose intake range is from 5.9 to 9.6 gm. In all groups the range was much broader when the data for the diet levels were considered. However, the low and high values occurred for animals on both diet levels, rather than just one diet level predominating. Thus, regardless of the concentration level, the amount of sucrose ingested was not significantly different; diet level and diet level by concentration level interaction also failed to produce significant results.

These data also cause a necessary re-evaluation in the position that palatability determines the amount of a solution ingested. If this were true, then, since the higher concentration would be ingested in greater amounts, the subsequent amount of sucrose ingested would be greater than that ingested at lower concentrations. However, in view of the results obtained, it appears as though caloric factors determined the lack of statistical significance in the amount of sucrose ingested. Since the caloric requirements of the individual rats would be basically the same, the actual amount of sucrose ingested by the rats would not be expected to be significantly different. Because of fairly set caloric requirements for each individual rat, its daily intake of sucrose solution would be adjusted, depending upon concentration, so as to meet caloric requirements. Therefore, in view of the above, an explanation of the significant results obtained for concentration level can be given. One must take into account the fact that the rats needed progressively more of a solution of lower concentration to obtain the same relative amount of sucrose available to the rats on the higher concentrations.

Scheffé's Test

Scheffé's test was performed on the data obtained concerning sucrose ingestion. The test was performed to see if there was a significant relationship between the high and normal diets and the differing concentrations. Each solution was studied in the light of the two diets so as to determine if by holding concentration level constant, the type of diet could lead to a significant difference in the amount of sucrose ingested. In Table VI, the statistical data obtained in performing the test are presented. Because of the wide disparity between obtained value for F and the required F', the results are not significant for either diet level at any of the concentration levels. Had significance been obtained, then one would predict that the type of diet was significantly adding to the caloric intake of the rat so as to require a decrease in sucrose ingestion. The possibility of the type of diet being so deficient in nutrient content such that the animal would need to markedly increase his sucrose intake and thus make up for nutrient not obtained from the diet would explain significance had it been obtained. However, since no statistical significance was found, one may assume that the diet levels were not sufficiently different in nutrient value in order to cause the rat markedly to change its intake of sucrose so as to compensate for the diet he was on. Rather, the nutrient content present in the diet appears to have combined with the main nutrient intake obtained from sucrose solutions.

TABLE VI

SCHEFFÉ'S TEST

Comparison

HC 1 M with NC 1 M = F_1

HC .5 M with NC .5 M = F_2

HC .25 M with NC .25 M = F_3

$$S_w^{\,2} = \frac{\sum \sum (X_{ij} - \bar{X}_{ij})^2}{n-k} = 18.54321 \qquad df = \frac{k-1}{n-k} = \frac{5}{1614}$$

Data:	N	$\bar{X}$	$\sum X^2$
HC 1 M	270	7.64583	19565.5832
HC .5 M	270	8.81233	25284.3888
HC .25 M	270	8.22183	24100.8047
NC 1 M	270	7.55950	19933.4907
NC .5 M	270	9.10267	25933.5565
NC .25 M	270	8.13483	25617.9276

$$F_1 = \frac{(\bar{X}_1 - X_2)^2}{S_w^{\,2}\,(N_1+N_2)/N_1N_2} \qquad F_2 = .61670 \qquad F_3 = .05974$$

$$= .05452$$

α .05 = 2.21 F' = 11.05

α .01 = 3.02 F' = 15.10

Thus,

F_1, F_2, F_3 are not significant

CHAPTER VI

DISCUSSION

From the results, one can conclude that apparently neither concentration nor dietary variations within the range employed nor their interaction was the determining factor in the amount of sucrose ingested. Rather, the determining factor appears to have been the caloric requirements of the individual rats.

In the experiment, a significant relationship failed to develop between type of diet and sucrose intake. From the hypothesis, one would have anticipated a relationship because the diet was expected to cause increased ingestion of a sucrose solution. Rather, it appears that the rats maintained their caloric balance primarily through the solutions of sucrose rather than through the diet or combining the two. This belief is further confirmed by the results obtained on sucrose ingestion and fluid intake. The F test performed on the possible interaction between diet and fluid concentration and amount of fluid ingested failed to meet significance. The high significance of the F test (37.543, df = 3/40,   .01) performed on concentration level and amount of fluid ingested would at first lead one to believe that palatability was the determining factor in intake. However, certain other results appear to lessen such a belief. In a brief exposure type of experiment, palatability would lead to the animal preferring the higher to the lower concentrations. These higher concentrations would manifest the greatest amounts of ingestion. Although, since this experiment involved a continuous choice situation, one would not expect the animals' to ingest more as the solutions were made more concentrated. A somewhat lower concentration than that found in the brief exposure situation would be expected to show the highest intake level. Rather, from the results, it was found that the higher the concentration, the lower the amount of solution ingested. Thus, the results fit into the belief that caloric factors predominate in sucrose ingestion. The rat ingested enough of a solution of meet his caloric requirement.

The F test performed on weight gain data failed to show a significant relationship between diet type and weight gain and also failed to show a significant relationship between sucrose concentration and weight gain. Any evidence of an interaction between diet and concentration failed to be shown by the results. These data help to confirm the belief that caloric factors were the prime factors in the rat's regulation of intake. The animals selected the amount of sucrose that would be necessary to balance the nutrient present in the diet available to them. Thus, the animals failed to become obese, as had been anticipated to occur due to the high palatability of the sucrose solutions. In spite of the high palatability of the sucrose solutions, caloric factors predominated, and the animals stopped eating when their caloric requirements were met, rather than eating to obesity.

The F test performed on the actual amount of sucrose ingested failed to show a significant relationship between diet and sucrose intake, concentration and sucrose intake or their interaction and sucrose intake. Such factors help give credence to the belief that caloric factors predominate over palatability in sucrose ingestion.

Because no significance was found for the amount of sucrose ingested, one can propose that the amount of sucrose present in various sucrose solution concentrations was equalized by the animals' varying amount ingested so as to maintain its caloric requirement.

Scheffé's test was performed on the data to determine if the differences in amounts of sucrose ingested of varying concentrations was a factor of the type of diet eaten. The test did not show significance with respect to the amount of a sucrose concentration ingested being a function of the type of diet. The data also lend support to the contention that caloric factors were the major determinants of the rat's ingestion. Therefore, dietary variations in sucrose were not the primary factors in affecting solution ingestion in the present study. Rather, one can assume that caloric factors were the primary determinants in affecting the amount of solution ingested.

In conclusion, the experiment gives support to the view that caloric factors are the predominating factors in regulating food intake in animals. In studies of the caloric intake of obese animals, experiments have found that when the obese animal is allowed to regulate his own intake caloric factors will predominate and the animal will eat to meet his bodily needs. Corbitt and Stellar (1964) found that forced feeding and insulin leads to obesity; however, when these were discontinued, the rats lost weight so as to reach the pretreatment levels. As the weight decreased, food intake increased. According to Teitelbaum and Epstein (1962), a variety of evidence states that taste and smell play a minor role in the long-term quantitative regulation of food and water intake. First, animals regulate their caloric intake over a wide range of dietary adulterations. Second, direct manipulation of the taste of the diet seems not to affect caloric intake at all. Last, regulation continues in the absence of taste and smell. According to Shuford (1959), sensations from the mouth, olfactory mucosa, and pharynx are of primary importance for the regulation of food intake in the wild, where the animal's survival is at stake. When the animal's only concern, however, is how much to eat, these factors become non-essential.

According to Adolph (1947) rats do, within certain limits, eat for calories. The urge to eat is governed to a large extent in accordance with the food's potential energy. An animal consumes as much of an available food as will improve his nutritive status (Adolph, 1947). Thus, the literature appears to support the view of calories as determining to a large part the animal's intake. Although the experiment was based upon conflicting views (Young, etc.) of taste and palatability leading a nondeprived animal to override caloric factors and approach obesity was not confirmed, the data from the experiment lend support to the view of caloric factors as being the prime determiners of food intake.

CHAPTER VII

SUMMARY

Forty-eight five month old white laboratory rats were divided into eight groups. These groups were placed on either a normal carbohydrate diet or on a high carbohydrate diet. The solutions presented were sucrose solutions of various concentrations, 1.0 M, .5 M, .25 M; the control group was on tap water. The animals were allowed to eat and drink _ad libitum_. Data were collected on the amount of solution ingested, weight gained, and sucrose ingested. The experiment was continued for forty-five days.

The experiment was designed to ascertain whether or not rats would ingest large quantities of sucrose at palatable concentrations and become obese. It was felt that the dietary effect would potentiate the solution effects so that the high carbohydrate animals would become more obese than the normal carbohydrate animals, regardless of solution. This design follows the basic views of Young and others. However, the results supported the views of the caloric proponents (Corbitt and Stellar, 1964; Teitelbaum, 1955; Shuford, 1959; and others). The results showed no significant relationship between diet and sucrose solution ingested, concentration of sucrose and diet interaction and sucrose solution ingested, diet or concentration or the interaction of them and weight gained, diet or concentration or the interaction of them and sucrose ingested. The only significant relationship, concentration level and solution ingested, merely adds support to the calorie viewpoint. The amount of sucrose ingested was not significantly different, yet the amount of solution ingested was. This fact can be explained by showing that enough of the various solutions were taken in so as to offset the differing amounts of sucrose present in the various concentrations. As the amount of water in the solutions increased, the rats increased their intake of the solutions so as to maintain their sucrose intake at a fairly constant level. Such results, as were obtained in the experiment, add to the belief that calories determined the amount of food ingested by an animal.

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APPENDIX

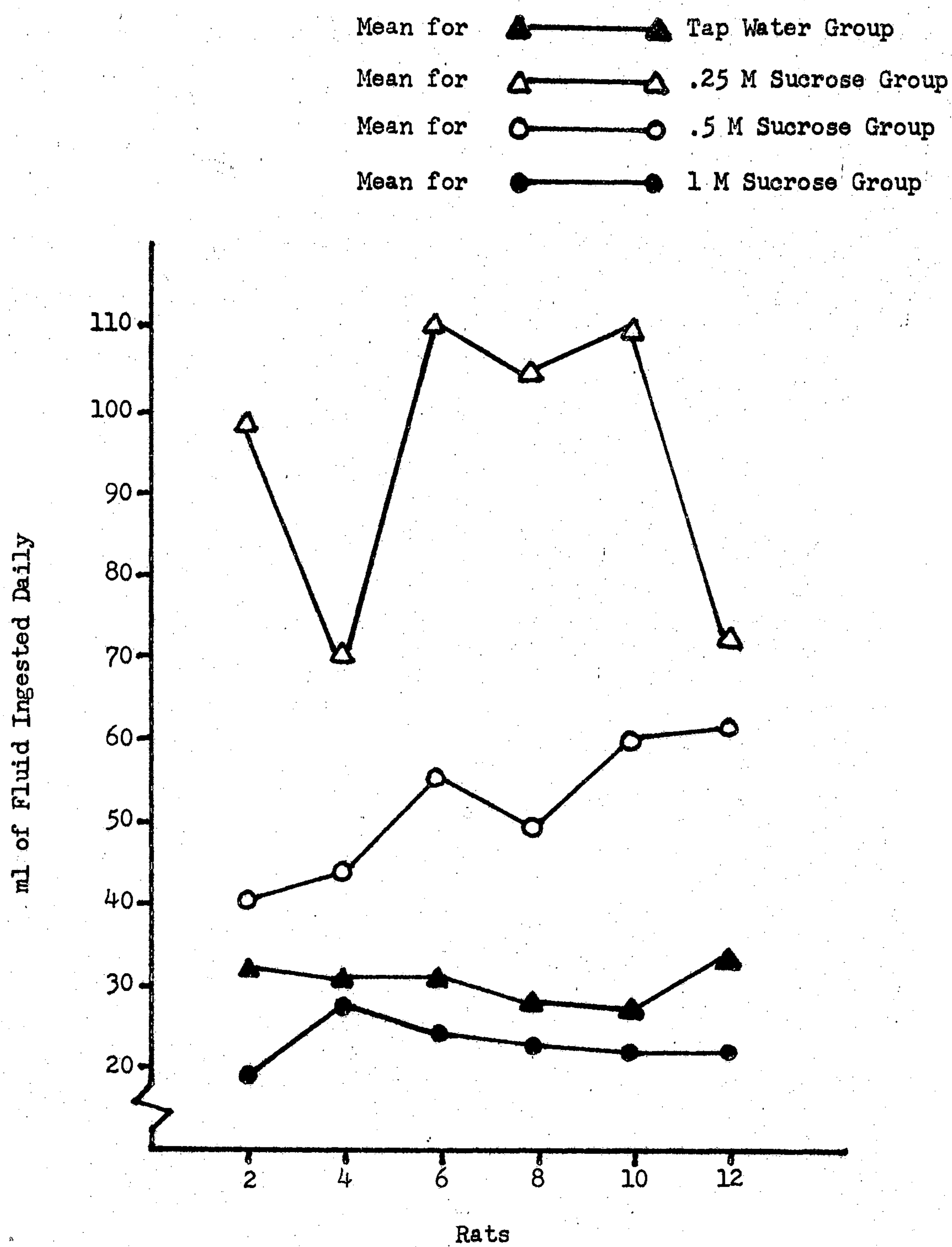

Figure 1. Mean Daily Fluid Intakes by Groups of Laboratory Rats (N = 12) for 45 Days

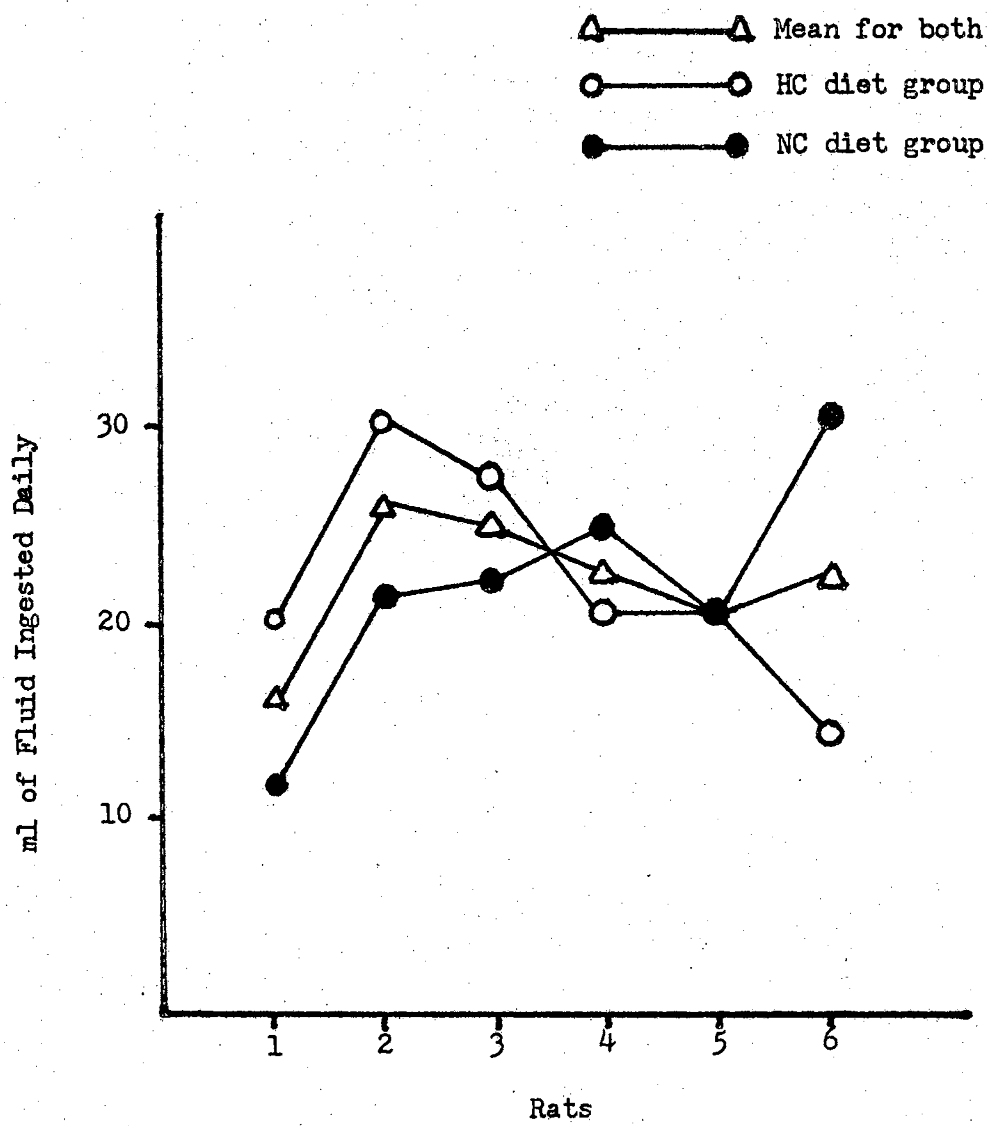

Figure 2. Mean Daily Fluid Intakes by Two Groups of Rats ($N = 6$) Maintained on 1.0 M Sucrose Solutions for 45 Days

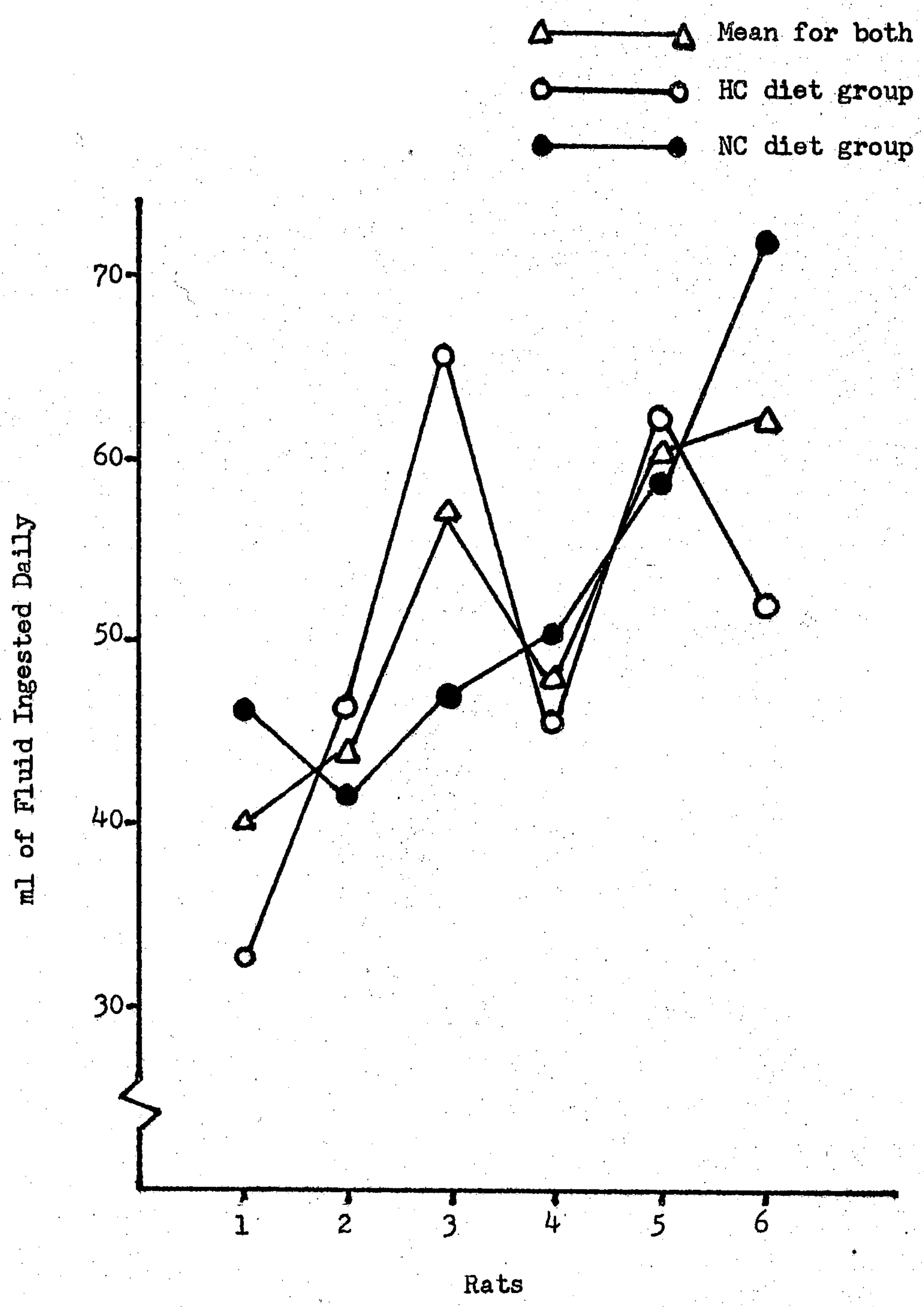

Figure 3. Mean Daily Fluid Intakes by Two Groups of Rats (N = 6) Maintained on .5 M Sucrose Solutions for 45 Days

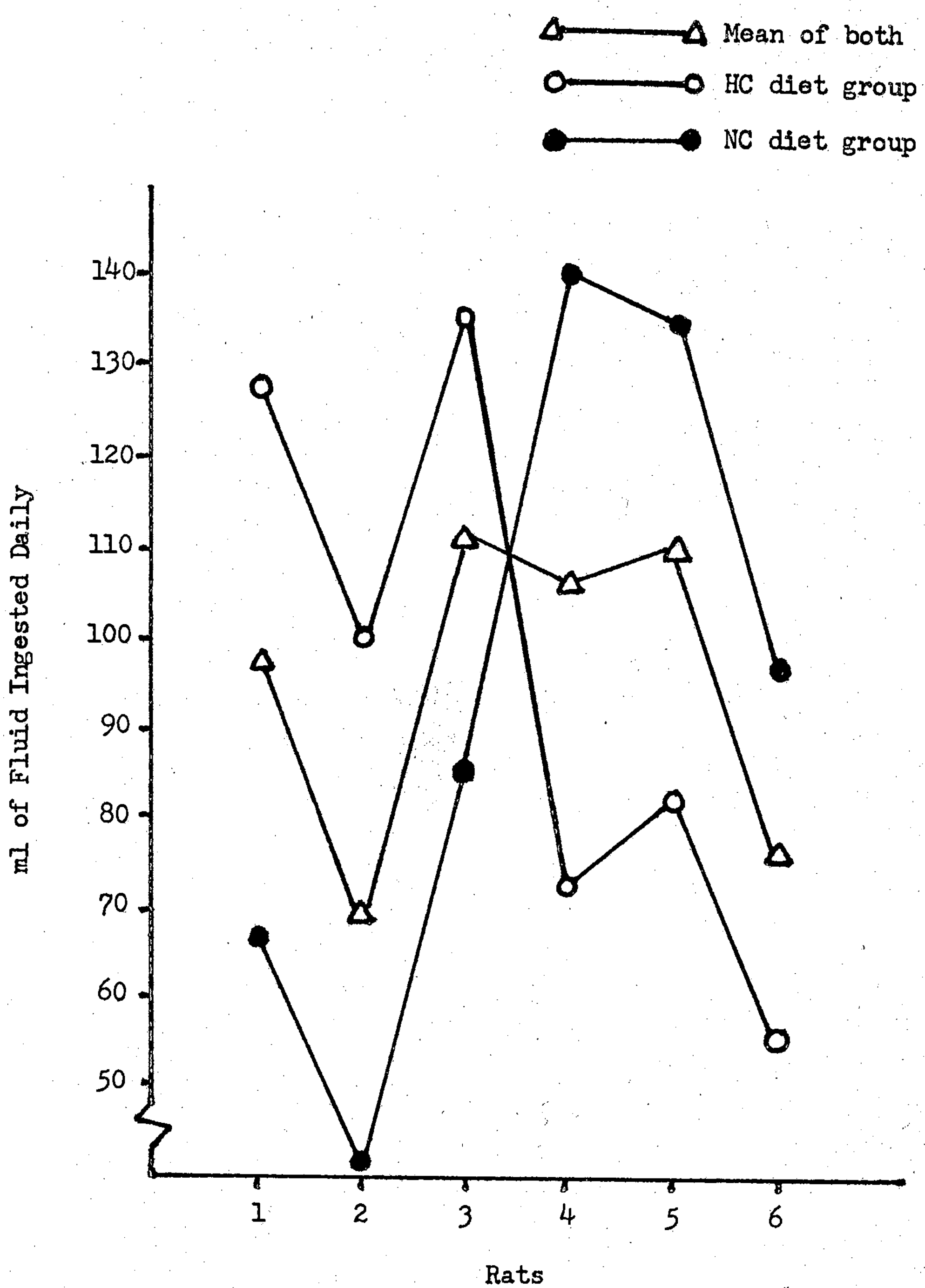

Figure 4. Mean Daily Fluid Intakes by Two Groups of Rats (N = 6) Maintained on .25 M Sucrose Solutions for 45 Days

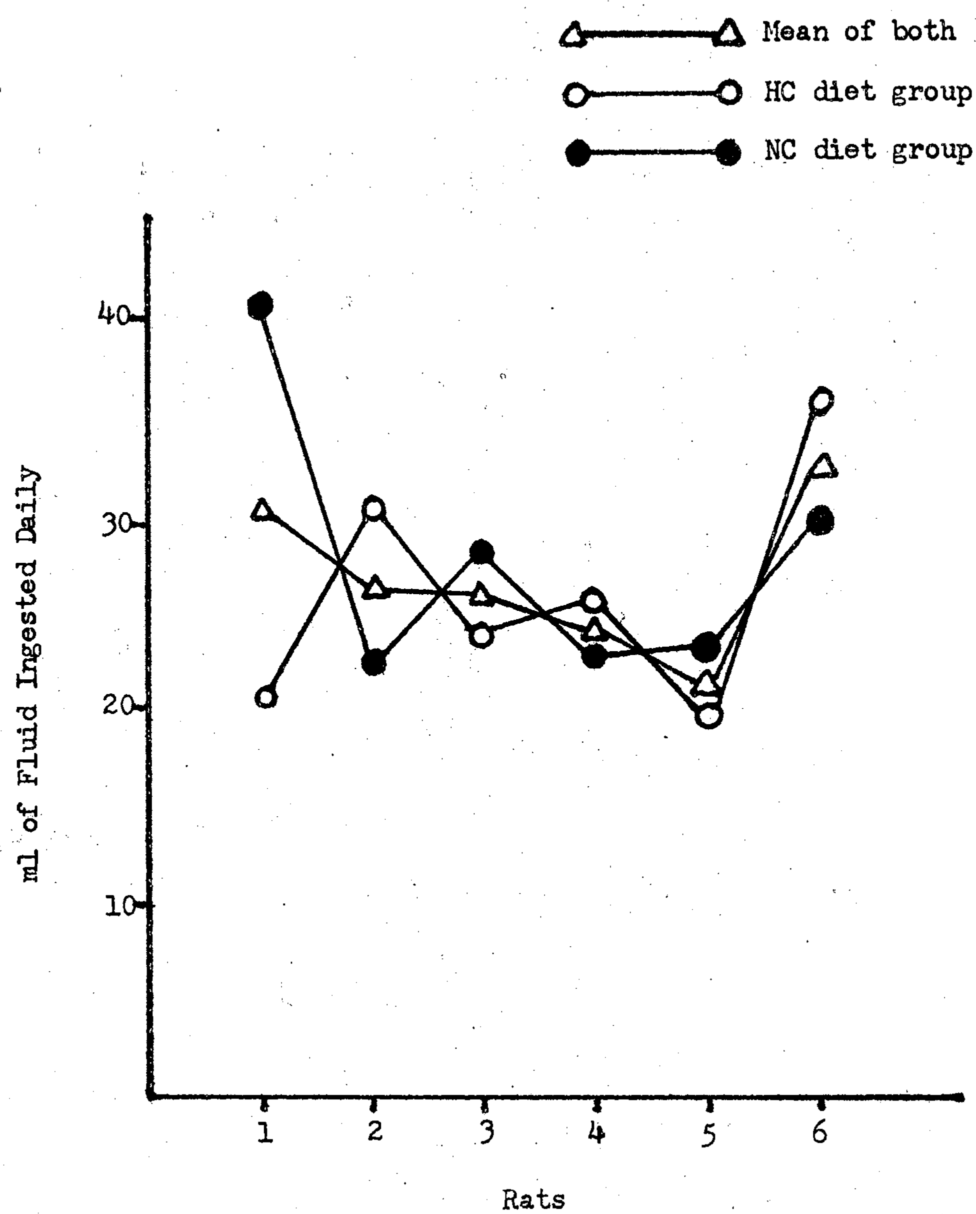

Figure 5. Mean Daily Fluid Intakes by Two Groups of Rats (N = 6) Maintained on Tap Water for 45 Days

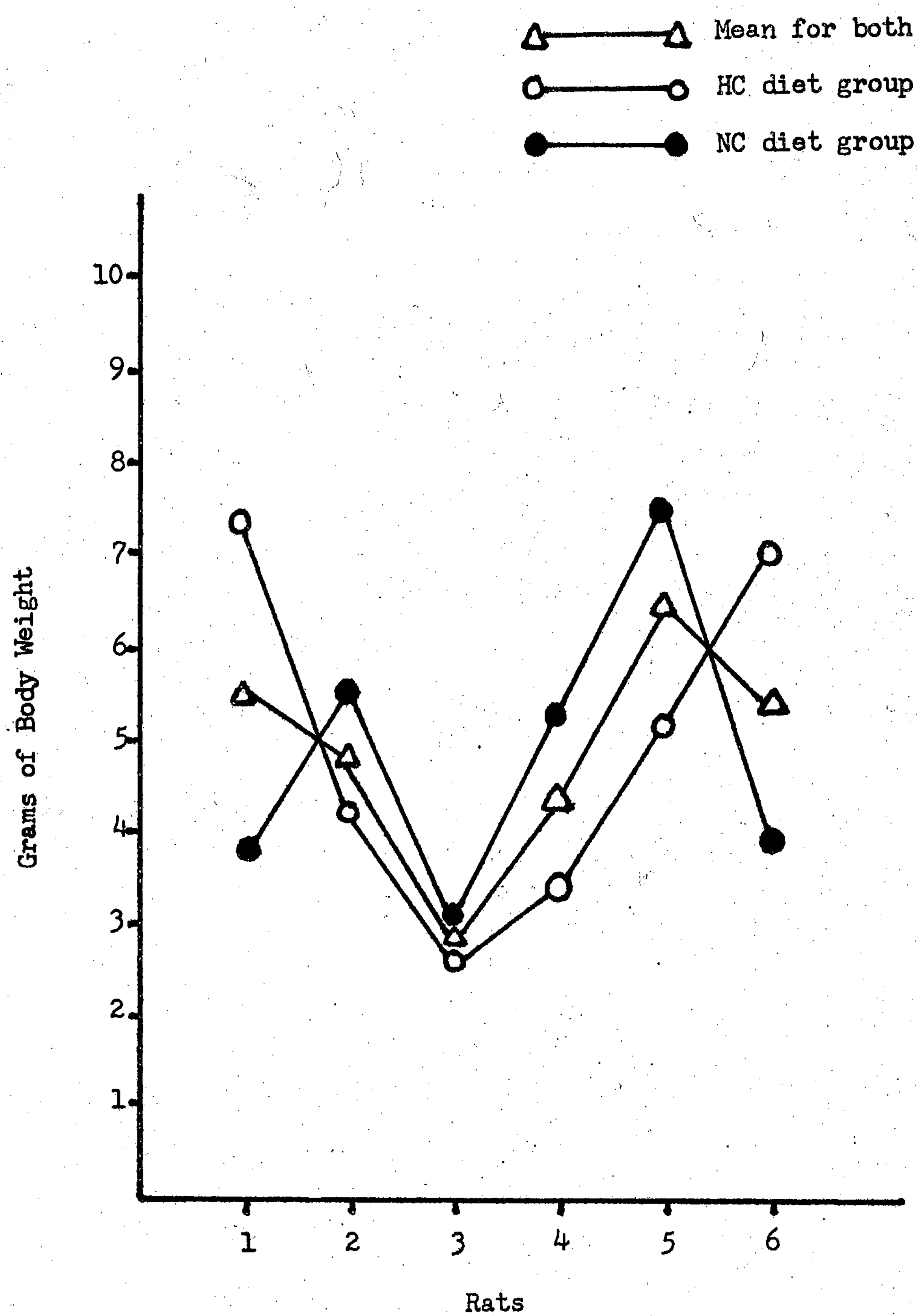

Figure 6. Mean Five Day Weight Gain Over 45 Days by Two Groups of Rats (N = 6) Given 1.0 M Sucrose Solutions

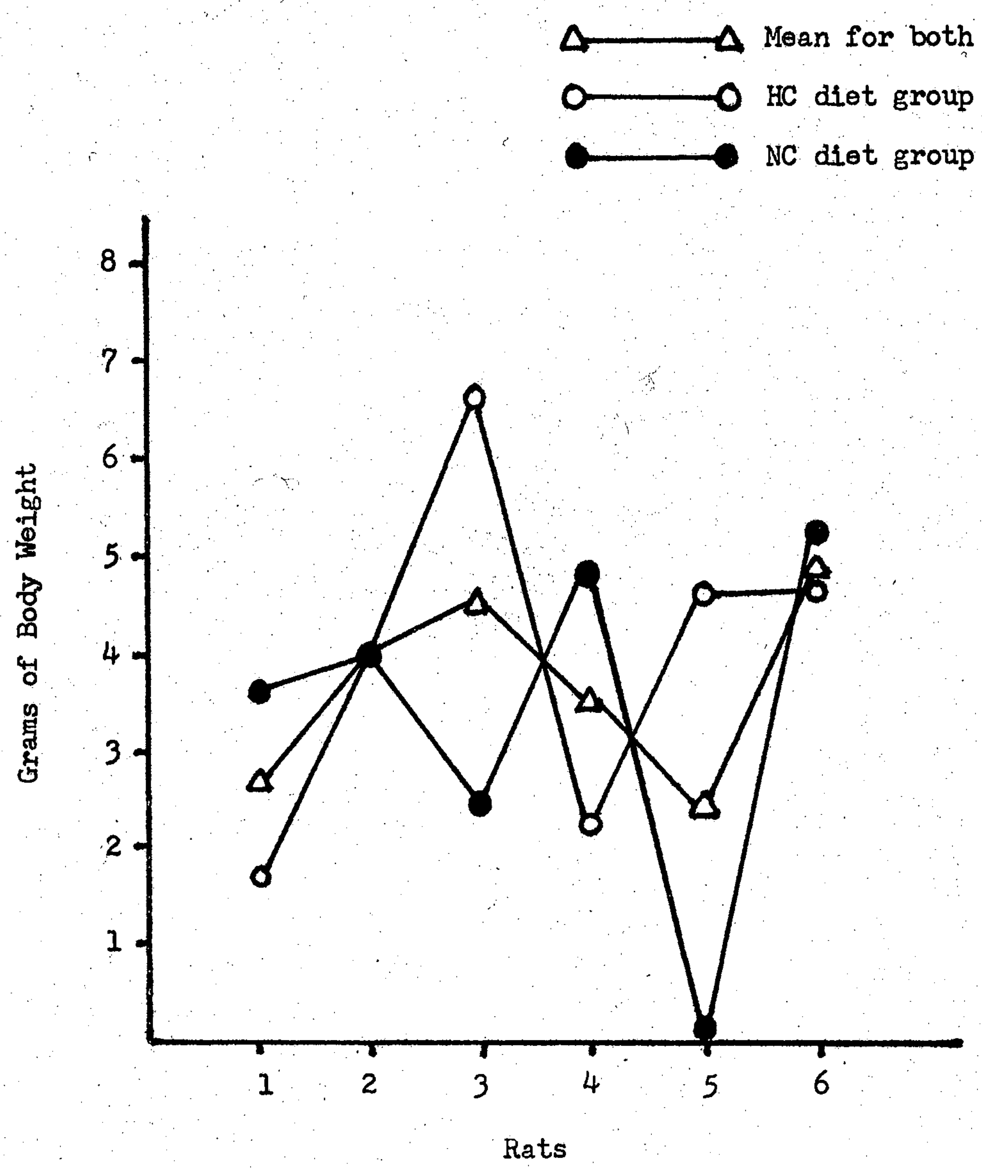

Figure 7. Mean Five Day Weight Gain Over 45 Days by Two Groups of Rats (N = 6) Given .5 M Sucrose Solutions

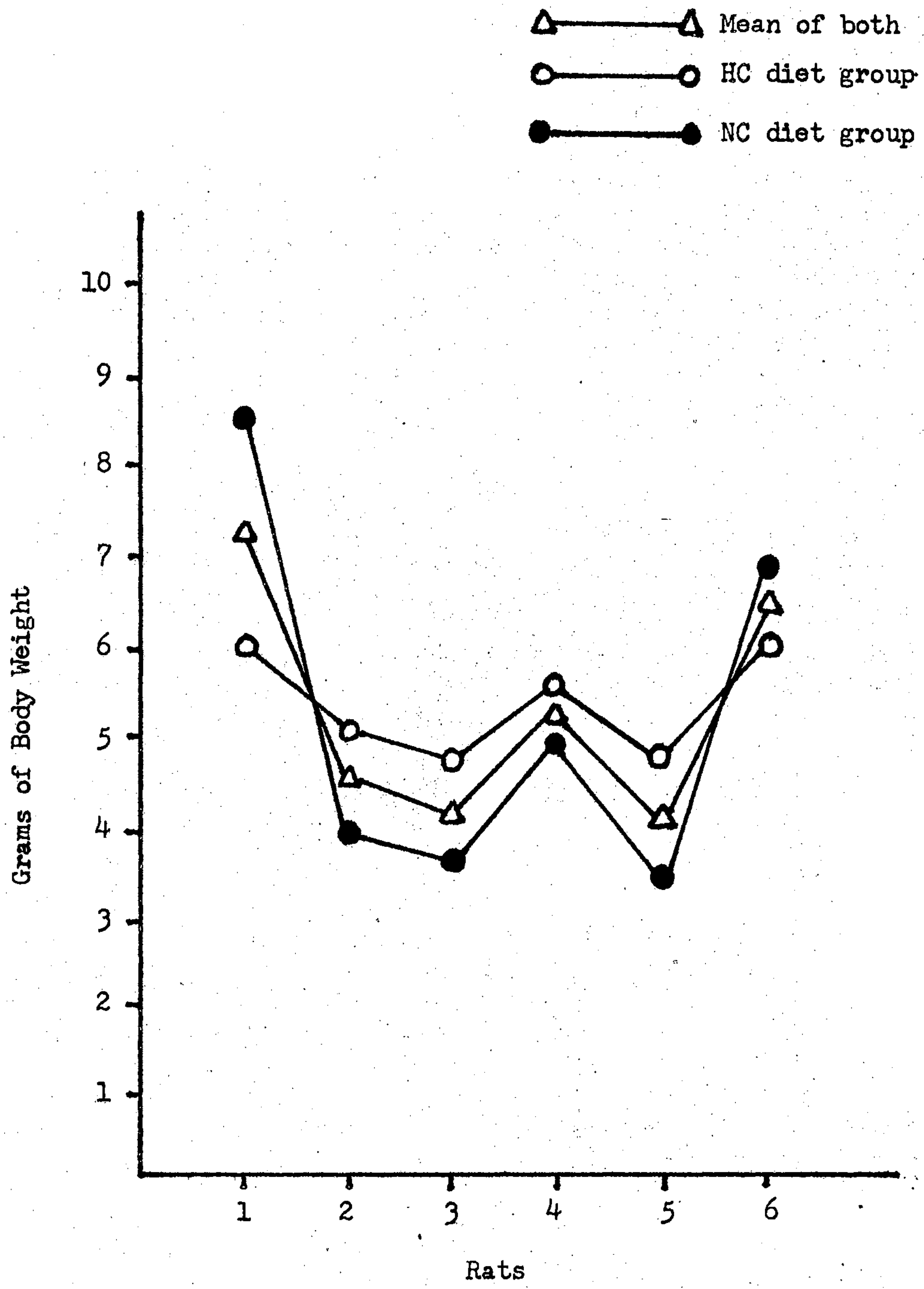

Figure 8. Mean Five Day Weight Gain Over 45 Days by Two Groups of Rats (N = 6) Given .25 M Sucrose Solutions

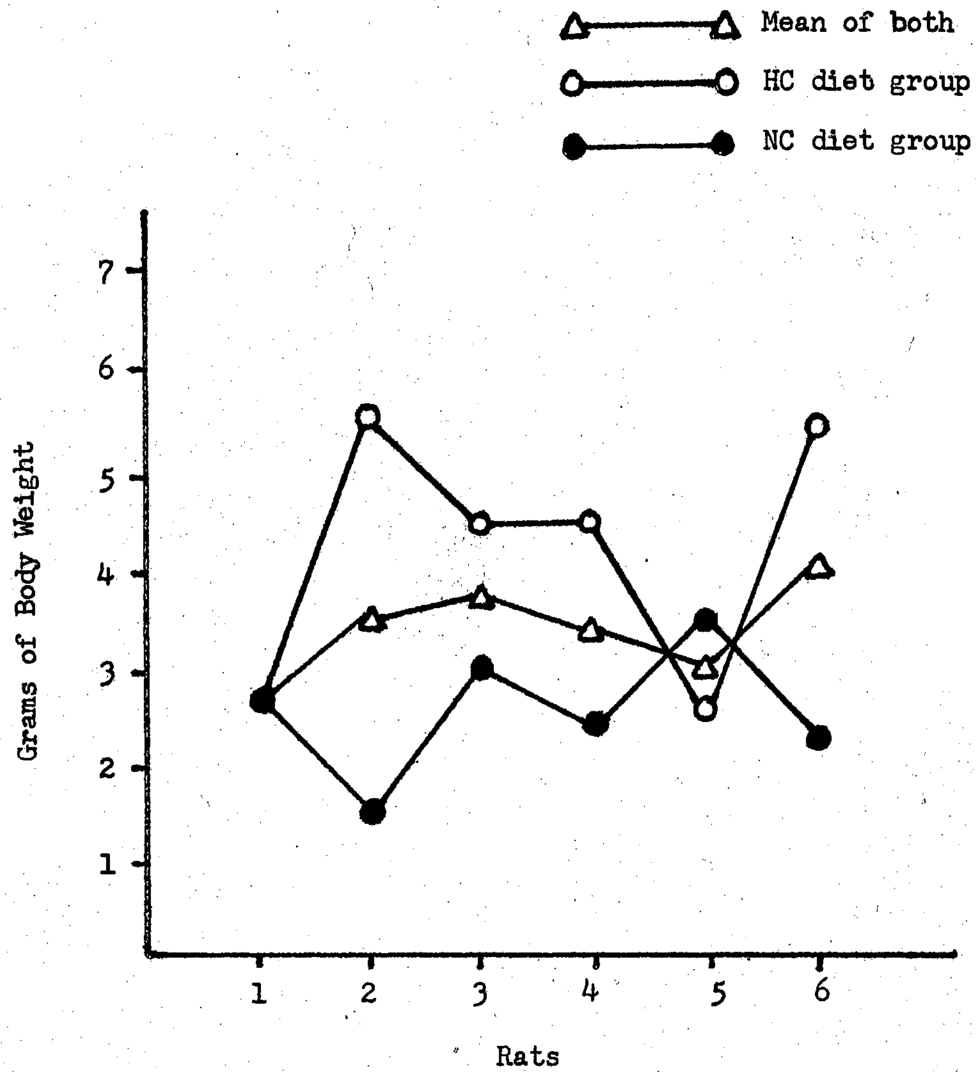

Figure 9. Mean Five Day Weight Gain Over 45 Days by Two Groups of Rats (N = 6) Given Tap Water

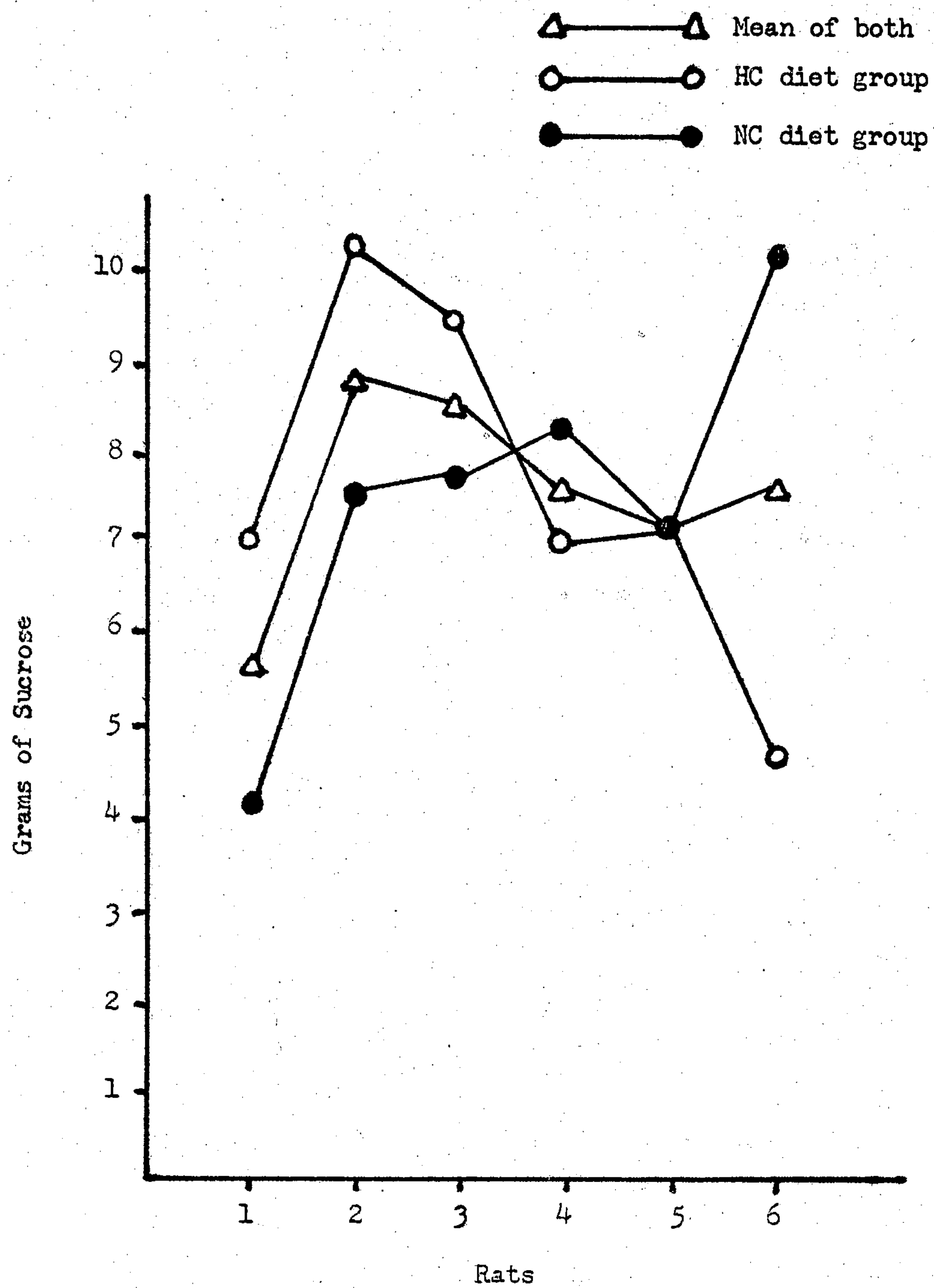

Figure 10. Mean Daily Sucrose Intake (In Grams) by Two Groups of Rats (N = 6) Given 1.0 M Sucrose Solutions for 45 Days

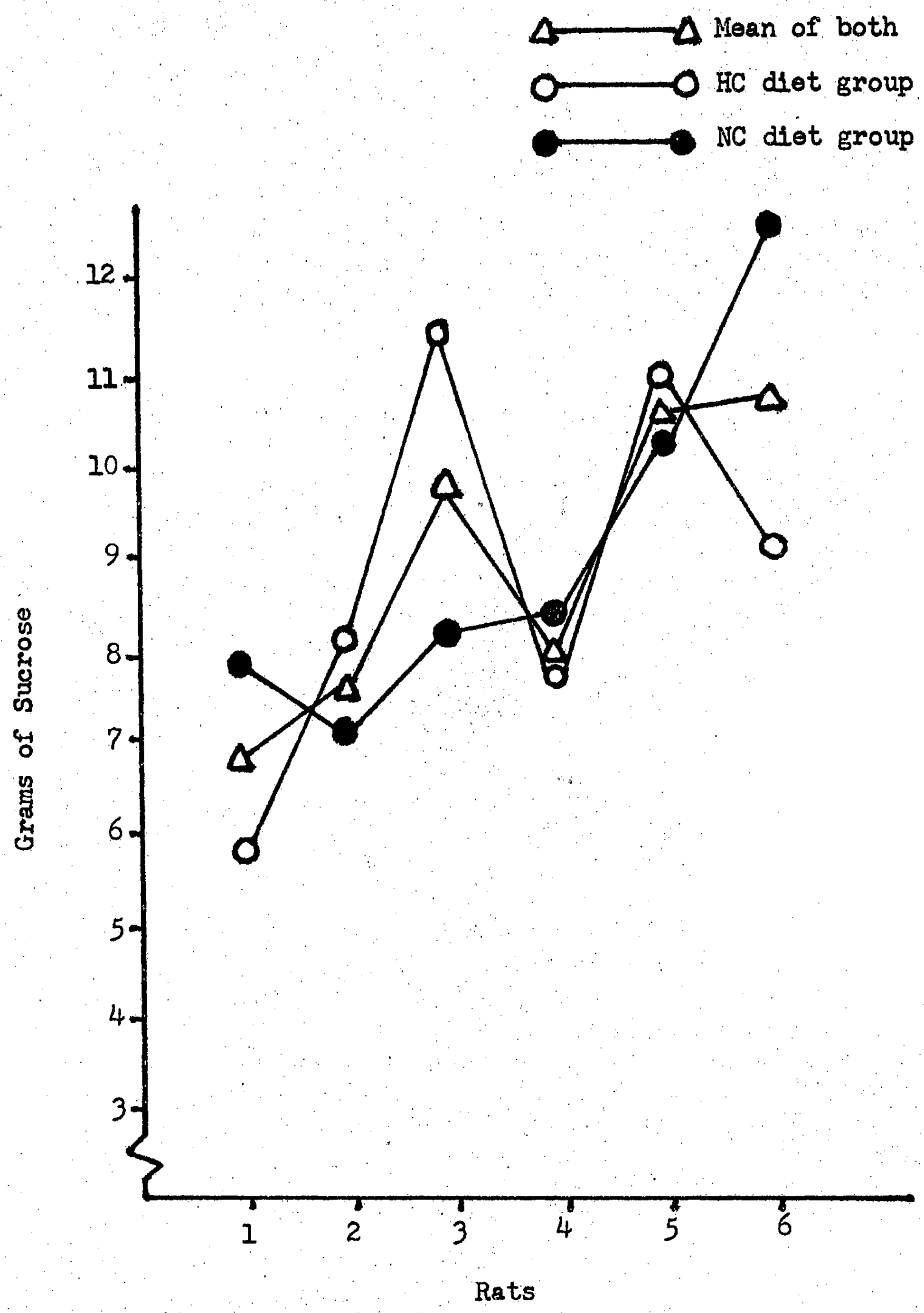

Figure 11. Mean Daily Sucrose Intake (In Grams) by Two Groups of Rats (N = 6) Given .5 M Sucrose Solutions for 45 Days

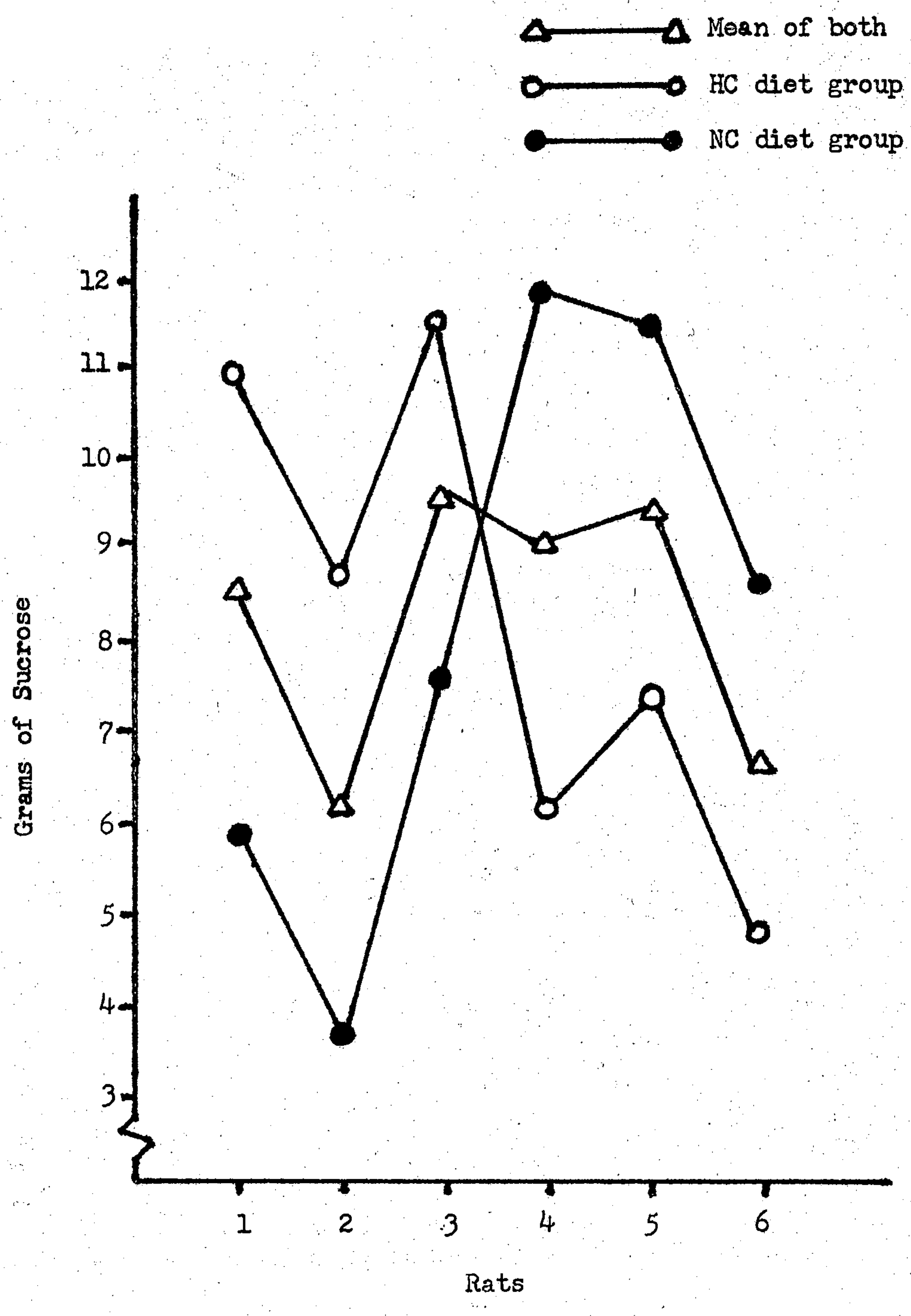

Figure 12. Mean Daily Sucrose Intake (In Grams) by Two Groups of Rats (N = 6) Given .25 M Sucrose Solutions for 45 Days

VITA

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Master of Science

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